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(54) **DUST REMOVAL APPARATUS OF PHOTOGRAPHING APPARATUS**
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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 572 days.

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(58) **Field of Classification Search** 348/374,
348/340, 219.1; 396/52-55
See application file for complete search history.

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(57) **ABSTRACT**

A dust removal apparatus of a photographing apparatus comprises a movable unit and a controller. The movable unit has an imaging device and is movable. The controller strikes the movable unit against a boundary of a range of movement of the movable unit as a dust removal operation. The controller counts the number of times of the dust removal operation, measures an elapsed time from the point when counting the number of times of the dust removal operation commences. When the elapsed time is less than or equal to a time period and the number of times of the dust removal operation is equal to or greater than a predetermined number of times, the controller halts the dust removal operation until a predetermined time period has elapsed.

16 Claims, 10 Drawing Sheets

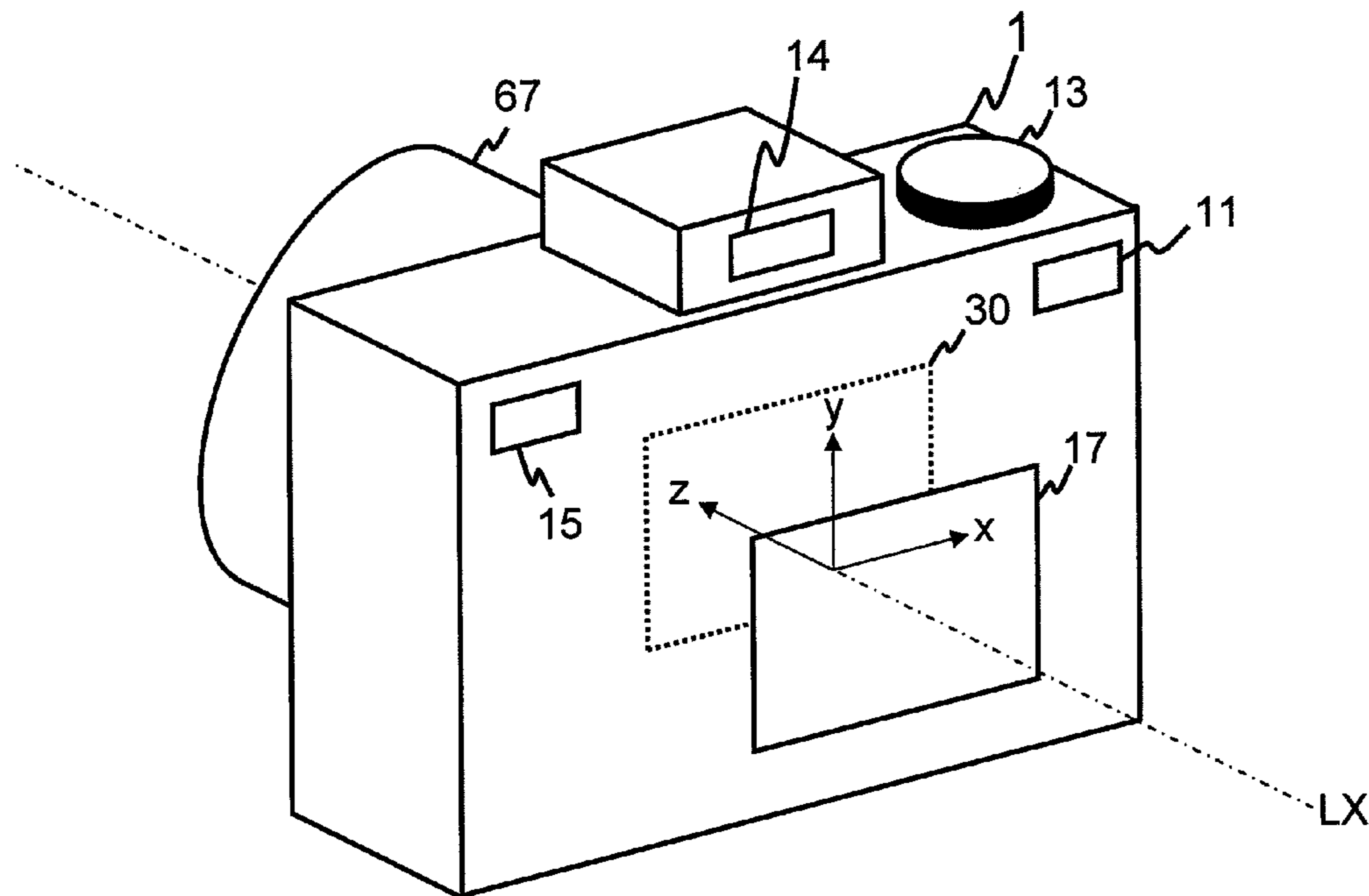


Fig. 1

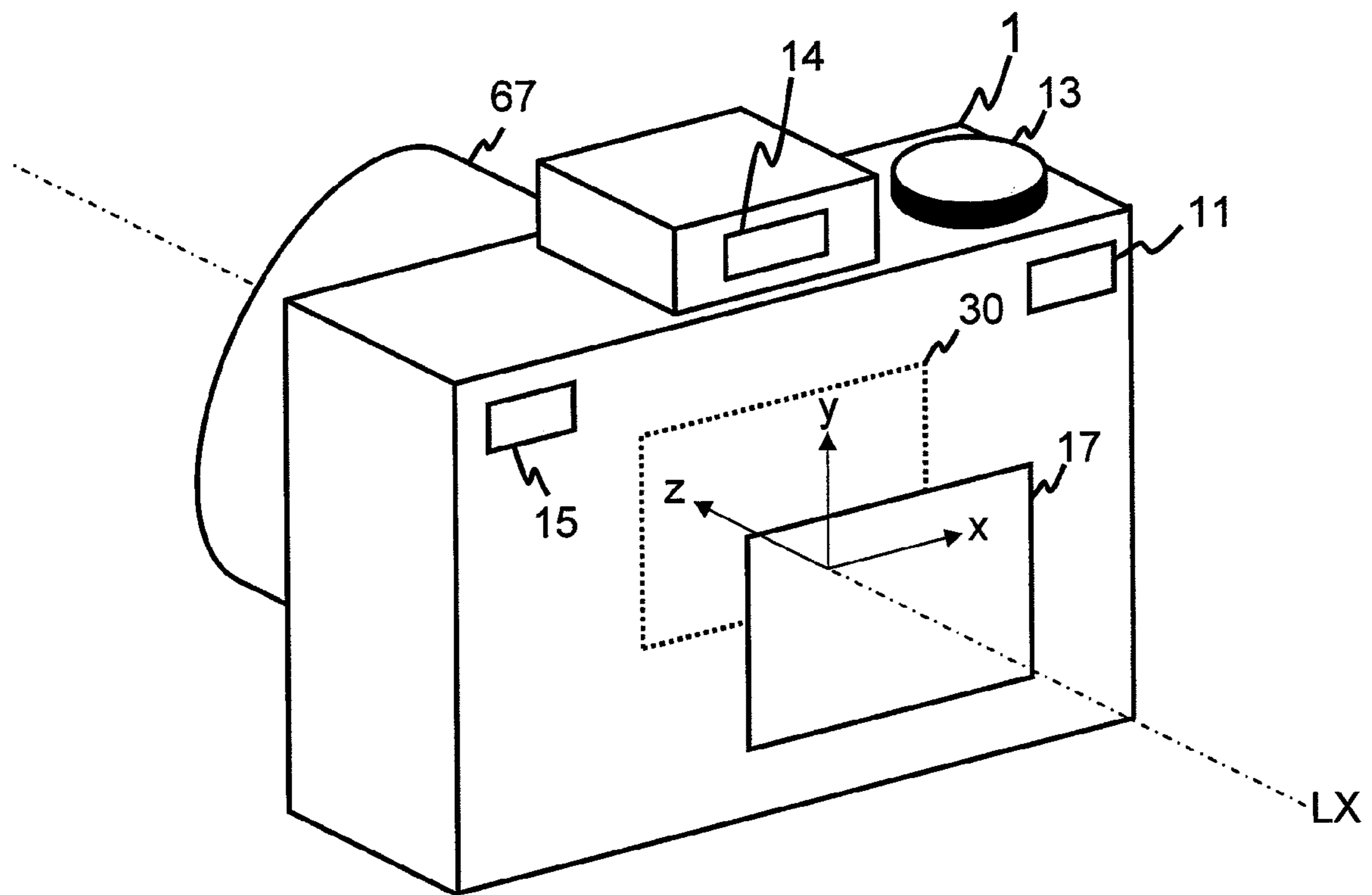


Fig. 2

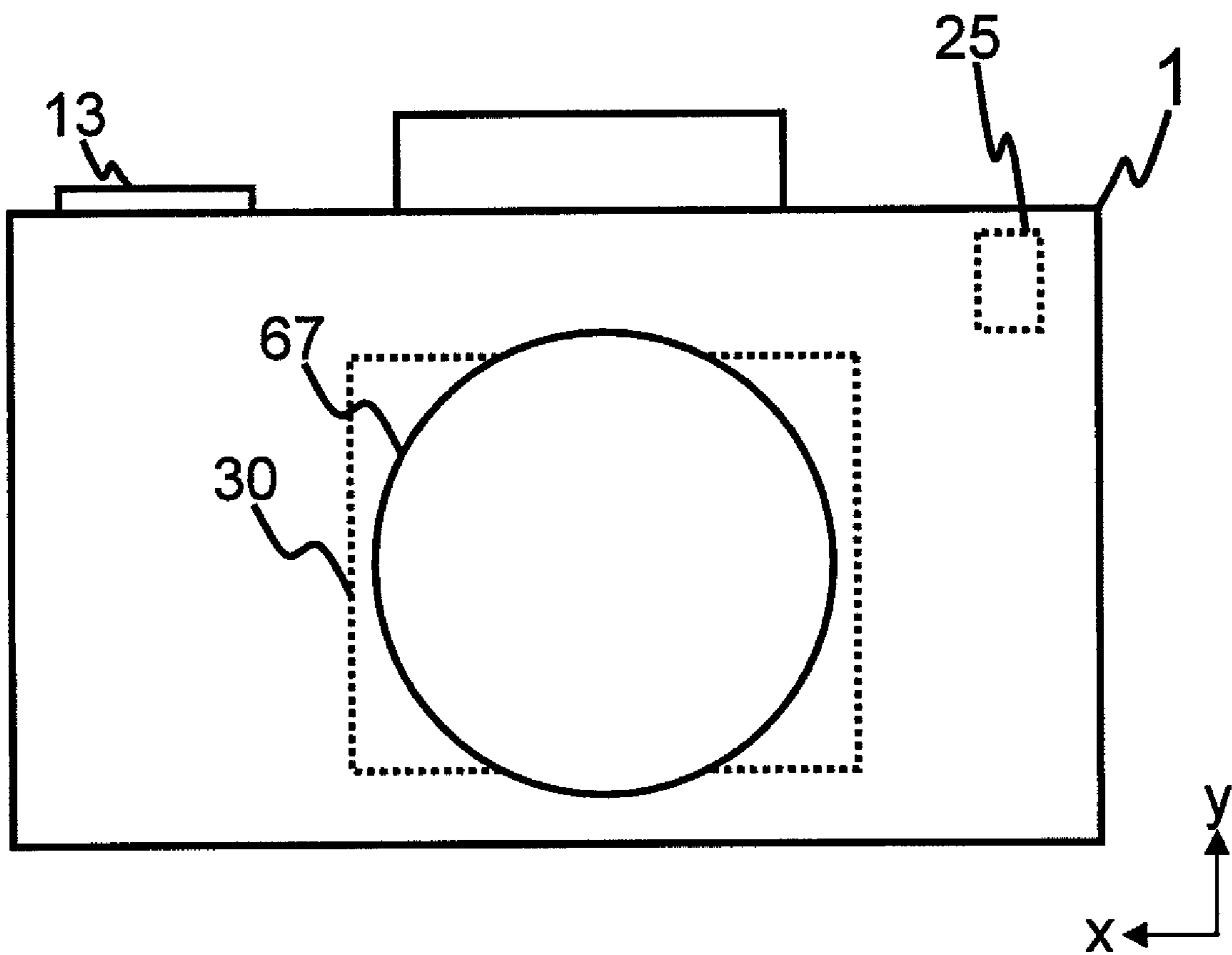


Fig. 5

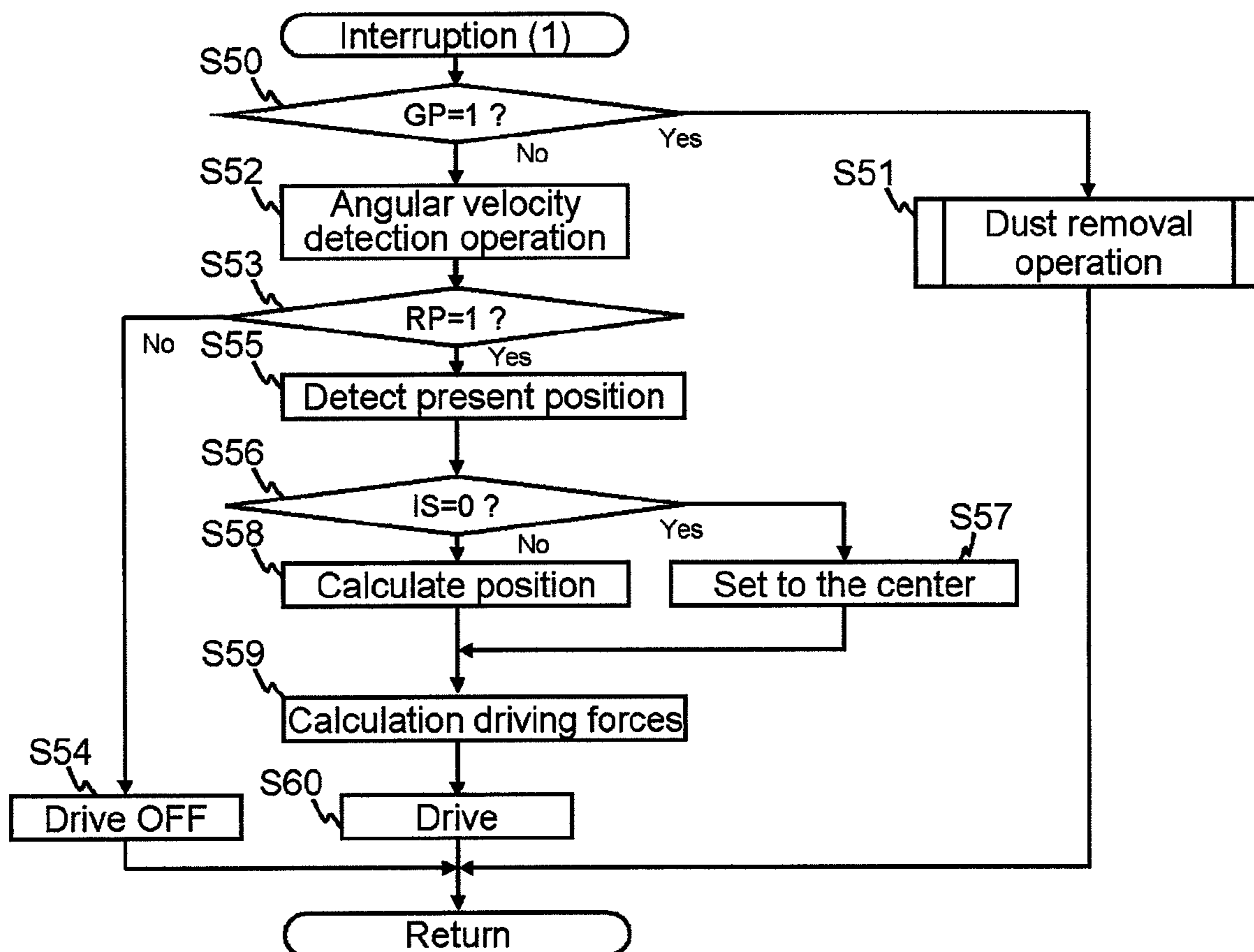


Fig. 6

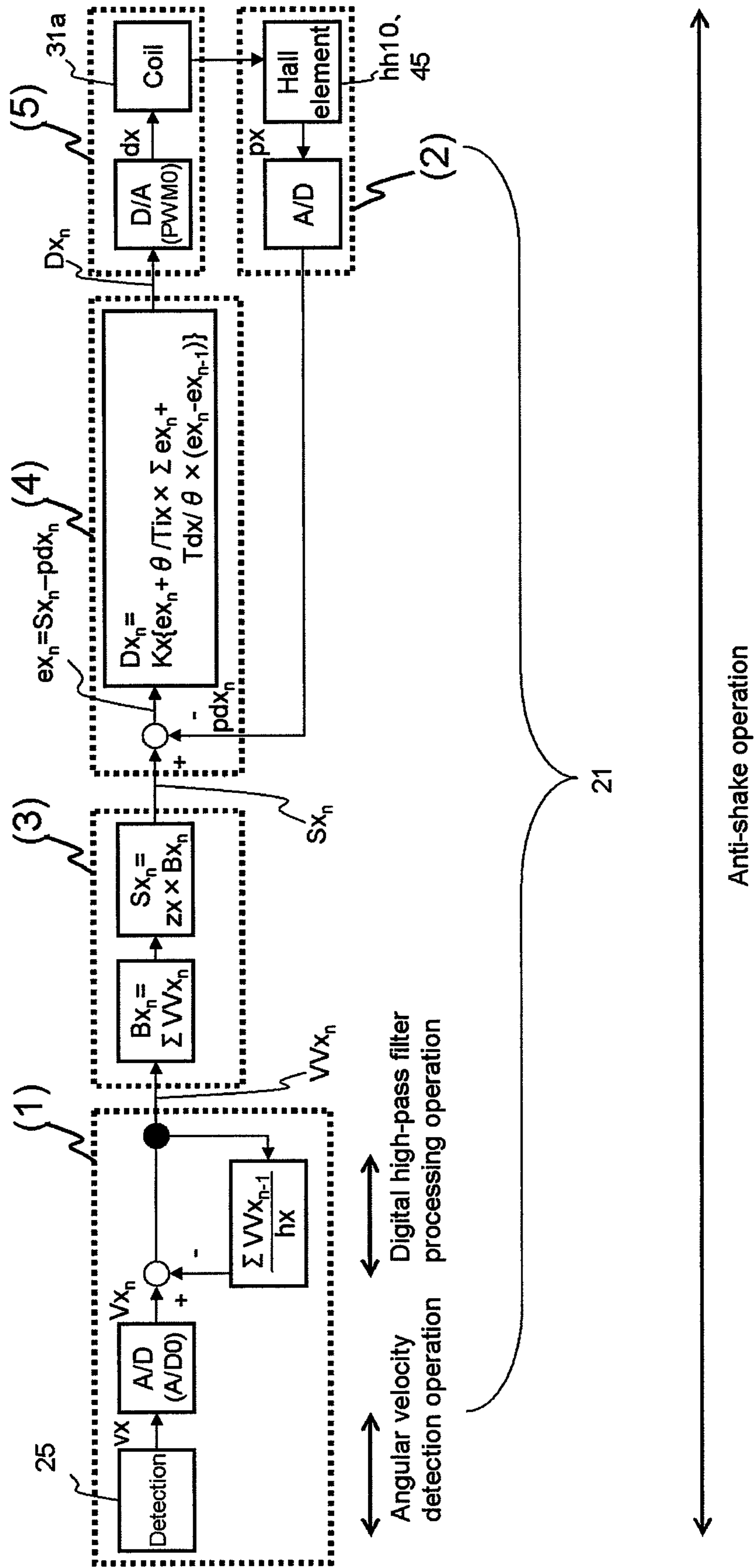


Fig. 7

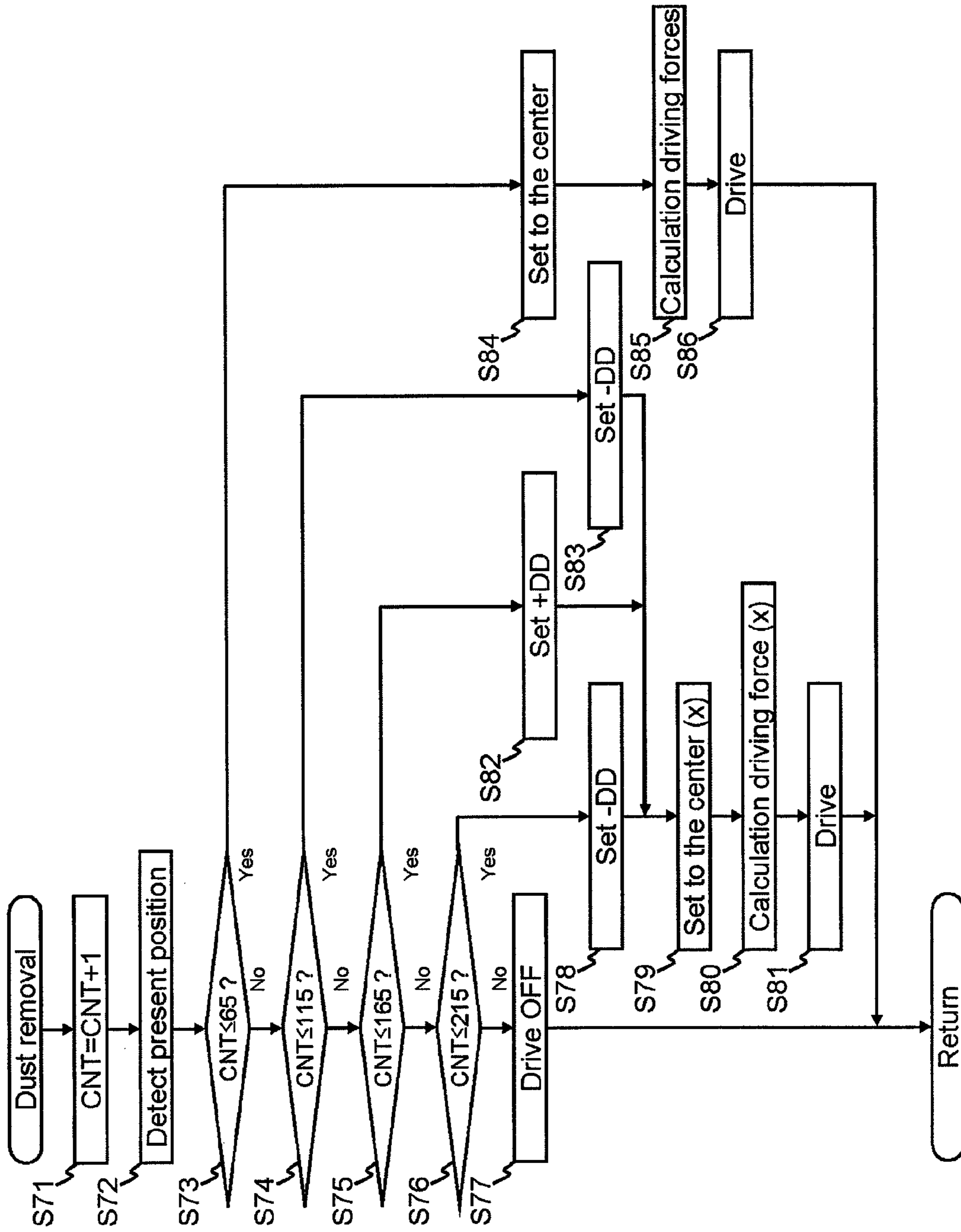


Fig. 8

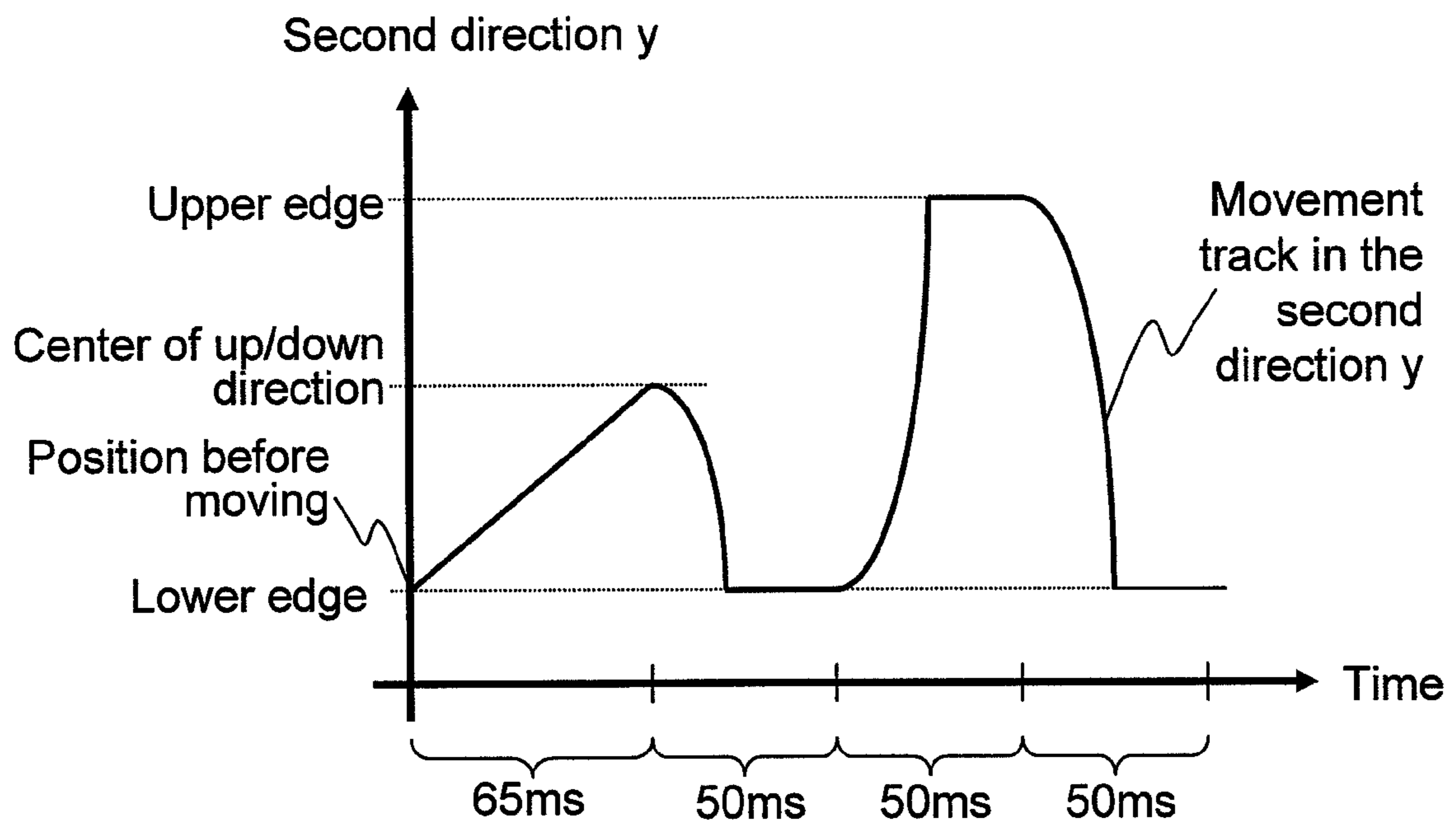


Fig. 9

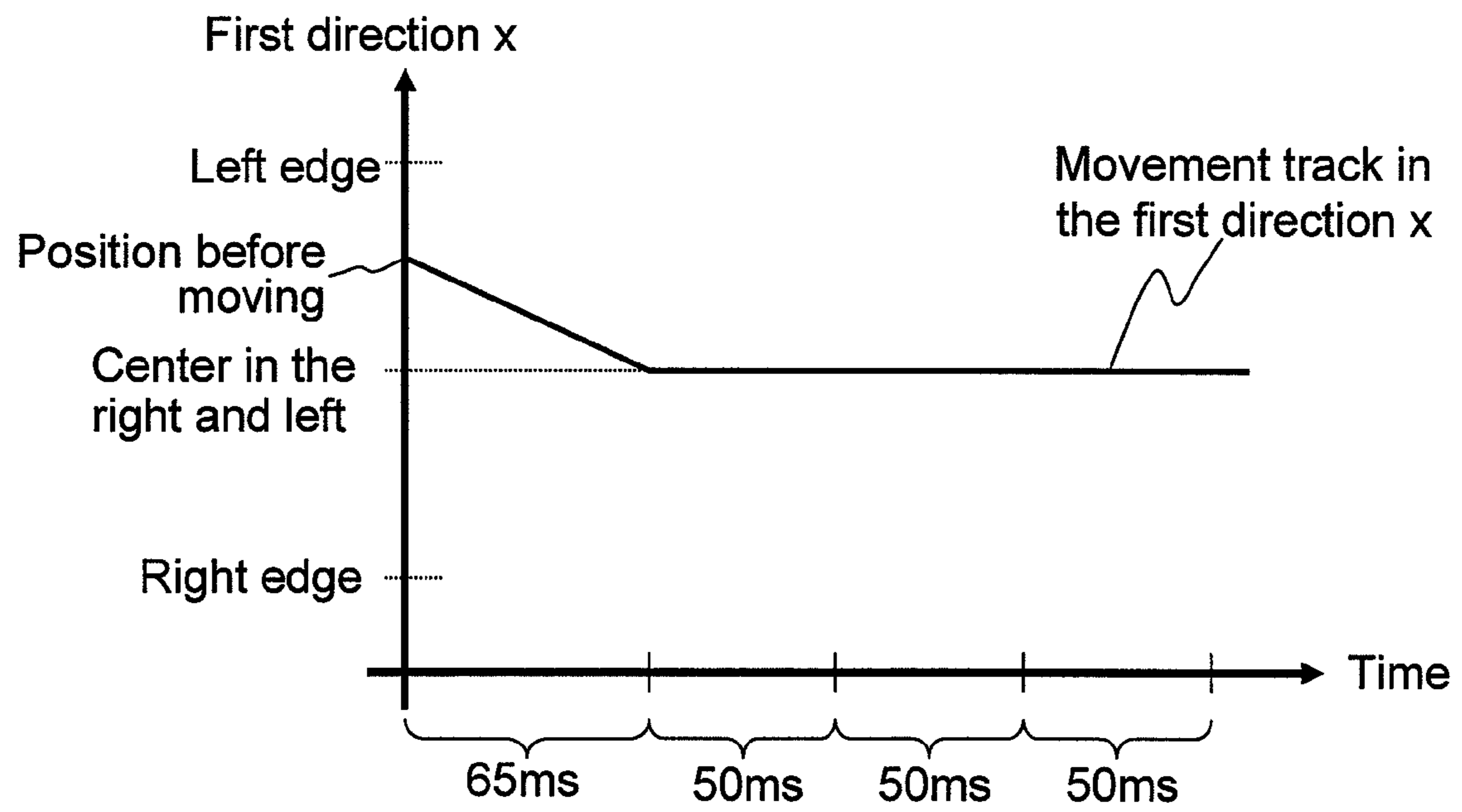
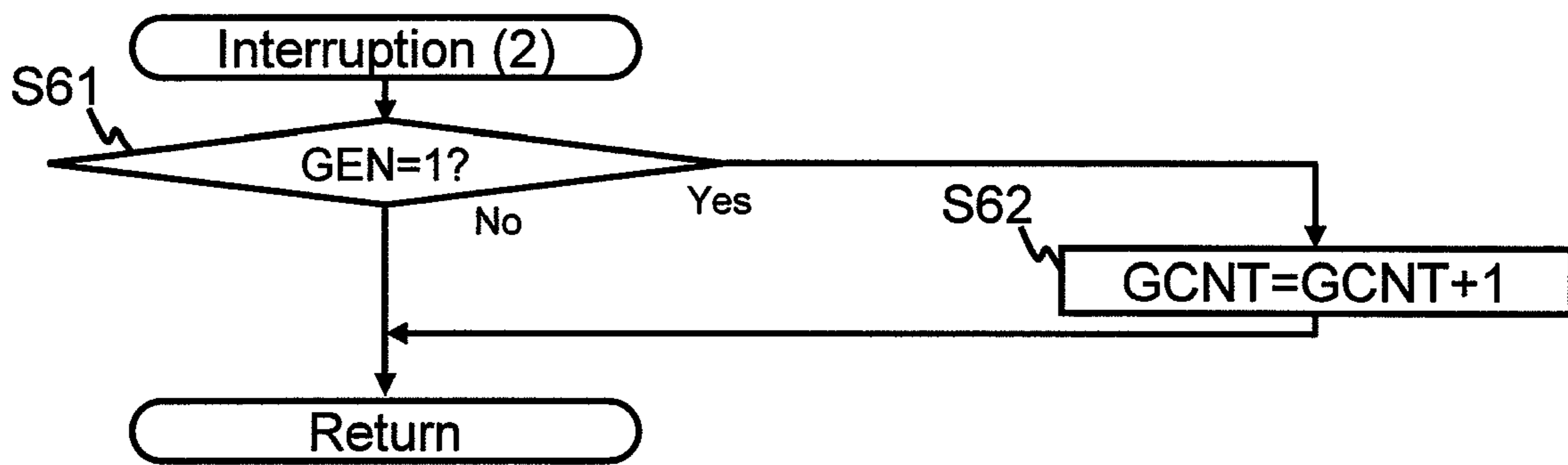


Fig. 10



1

DUST REMOVAL APPARATUS OF
PHOTOGRAPHING APPARATUS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a dust removal apparatus of a photographing apparatus, and in particular to restrain the damage to the mechanism caused by the dust removal operation.

2. Description of the Related Art

A dust removal apparatus of a photographing apparatus, that removes the dust on the imaging device and the cover such as the low-pass filter, is proposed.

Japanese unexamined patent publication (KOKAI) No. 2005-340988 discloses a dust removal apparatus that strikes the movable unit including the imaging device against the boundary of the range of movement of the movable unit so that the shock of impact will remove the dust on the imaging device and the cover etc.

However, the movable unit **30a** etc. may sustain damage caused by heat and shock from continuous impact between the movable unit and the boundary of the range of movement of the movable unit.

SUMMARY OF THE INVENTION

Therefore, an object of the present invention is to provide a dust removal apparatus that reduces damage the mechanism during the dust removal operation and removes the dust more efficiently.

According to the present invention, a dust removal apparatus of a photographing apparatus comprises a movable unit and a controller. The movable unit has an imaging device and is movable. The controller strikes the movable unit against a boundary of a range of movement of the movable unit as a dust removal operation. The controller counts the number of times of the dust removal operation, measures an elapsed time from the point when counting the number of times of the dust removal operation commences. When the elapsed time is less than or equal to a time period and the number of times of the dust removal operation is equal to or greater than a predetermined number of times, the controller halts the dust removal operation until a predetermined time period has elapsed.

BRIEF DESCRIPTION OF THE DRAWINGS

The objects and advantages of the present invention will be better understood from the following description, with reference to the accompanying drawings in which:

FIG. 1 is a rearview perspective of the embodiment of the photographing apparatus viewed from the back side;

FIG. 2 is a front view of the photographing apparatus;

FIG. 3 is a circuit construction diagram of the photographing apparatus;

FIG. 4 is a flowchart that shows the main operation of the photographing apparatus;

FIG. 5 is a flowchart that shows the detail of the first interruption process of the timer;

FIG. 6 is a figure that shows the calculations of the anti-shake operation;

FIG. 7 is a flowchart that shows the dust removal operation;

FIG. 8 is a graph that shows the relationship between an elapsed time and the position of the movable unit in the second direction in the dust removal operation;

2

FIG. 9 is a graph that shows the relationship between an elapsed time and the position of the movable unit in the first direction in the dust removal operation; and

FIG. 10 is a flowchart that shows the detail of the second interruption process of the timer.

DESCRIPTION OF THE PREFERRED
EMBODIMENTS

The present invention is described below with reference to the embodiment shown in the drawings. In the embodiment, the photographing apparatus **1** is a digital camera. A photographing optical system, such as a camera lens **67** etc., that captures (images) an optical image on a photographing surface of the imaging device of the photographing apparatus **1** has an optical axis LX.

In order to explain the orientation of the embodiment, a first direction x, a second direction y, and a third direction z are defined (see FIG. 1). The first direction x is perpendicular to the optical axis LX. The second direction y is perpendicular to the optical axis LX and the first direction x. The third direction z is parallel to the optical axis LX and perpendicular to both the first direction x and the second direction y.

The imaging and the dust removal part (the dust removal apparatus) of the photographing apparatus **1** comprises a PON button **11**, a PON switch **11a**, a photometric switch **12a**, a release button **13**, a release switch **13a**, an anti-shake button **14**, an anti-shake switch **14a**, a dust removal button **15**, a dust removal switch **15a**, an indicating unit **17** such as an LCD monitor etc., a mirror-aperture-shutter unit **18**, a DSP **19**, a CPU **21**, an AE (automatic exposure) unit **23**, an AF (automatic focus) unit **24**, an anti-shake unit **30**, and a camera lens **67** (see FIGS. 1, 2, and 3).

Whether the PON switch **11a** is in the ON state or the OFF state is determined by the state of the PON button **11**, so that the ON/OFF states of the photographing apparatus **1** correspond to the ON/OFF states of the PON switch **11a**.

The photographic subject image is captured as the optical image through the camera lens **67** by the imaging unit **39a**, and the captured image is displayed on the indicating unit **17**. The photographic subject image can be optically observed by the optical finder (not depicted).

Further, after the PON button **11** is depressed so that the photographing apparatus **1** is set to the ON state, a dust removal operation is performed in a first time period (220 ms).

The number of times of the dust removal operation, from the point when counting the number of times of the dust removal operation commences (the point when the first dust removal operation commences) to the point when a third time period (10000 ms) has elapsed, is limited to less than or equal to the predetermined number of times (10 times) in order to prevent damage to the movable unit **30a** etc. caused by the heat and shock from continuous impact between the movable unit **30a** and the boundary of the range of movement of the movable unit **30a**. The control of the limitation of the number of times of the dust removal operation is explained later.

When the release button **13** is partially depressed by the operator, the photometric switch **12a** changes to the ON state so that the photometric operation, the AF sensing operation, and the focusing operation are performed.

When the release button **13** is fully depressed by the operator, the release switch **13a** changes to the ON state so that the imaging operation by the imaging unit **39a** (the imaging apparatus) is performed, and the image which is captured, is stored.

Whether the dust removal switch **15a** is in the ON state or the OFF state is determined by the state of the dust removal button **15**.

The mirror-aperture-shutter unit **18** is connected to port P7 of the CPU **21** and performs an UP/DOWN operation of the mirror (a mirror-up operation and a mirror-down operation), an OPEN/CLOSE operation of the aperture, and an OPEN/CLOSE operation of the shutter corresponding to the ON state of the release switch **13a**.

The DSP **19** is connected to port P9 of the CPU **21**, and it is connected to the imaging unit **39a**. Based on a command from the CPU **21**, the DSP **19** performs the calculation operations, such as the image processing operation etc., on the image signal obtained by the imaging operation of the imaging unit **39a**.

The CPU **21** is a control apparatus that controls each part of the photographing apparatus **1** regarding the imaging operation, the dust removal operation, and the anti-shake operation (i.e. the image stabilizing operation). The anti-shake operation includes both the movement of the movable unit **30a** and position detection efforts.

Further, the CPU **21** stores a value of the anti-shake parameter IS that determines whether the photographing apparatus **1** is in the anti-shake mode or not, a value of a release state parameter RP, a value of a dust removal state parameter GP, a value of a dust removal time parameter CNT, a value of a count start parameter GEN, a value of a time count parameter GCNT, and a value of a number count parameter NUG.

The value of the release state parameter RP changes with respect to the release sequence operation. When the release sequence operation is performed, the value of the release state parameter RP is set to 1 (see steps S33 to S40 in FIG. 4); and when the release sequence operation is finished, the value of the release state parameter RP is set (reset) to 0 (see steps S13 and S41 in FIG. 4).

The dust removal state parameter GP is a parameter that indicates whether the dust removal operation is finished.

The value of the dust removal state parameter GP is set to 1 when the dust removal operation is underway, under the first condition from the point in time when a dust removal operation commences until the point in time when the dust removal operation is finished, and under the second condition (see step S22 in FIG. 4).

The value of the dust removal state parameter GP is set to 0 at the completion of the dust removal operation; in other words, when the first time period (220 ms) that began with the commencement of the dust removal operation has elapsed (see step S24 in FIG. 4).

The second condition occurs when the dust removal switch **15a** is set to the ON state and either the third time period (10000 ms), which began with the commencement of counting the number of times of the dust removal operation, has elapsed; or the third time period that began with the commencement of counting the number of times of the dust removal operation has not yet elapsed and the number of times of the dust removal operation has not been equal to or greater than the predetermined number of times (10 times).

The dust removal time parameter CNT is used for measuring the length of time it takes to perform one dust removal operation. An initial value of the dust removal time parameter CNT is set to 0. While the dust removal operation is being performed, the value of the dust removal time parameter CNT is increased by the value of 1 at every predetermined time interval of 1 ms. (see step S71 in FIG. 7).

The count start parameter GEN is used for measuring the continuous length of time the dust removal operations are performed (the elapsed time from the point when counting the

number of times of the dust removal operation commences) The value of the count start parameter GEN is set to 1, under the first and second conditions. Otherwise, the value of the count start parameter GEN is set to 0.

The time count parameter GCNT is used for measuring the continuous length of time the dust removal operations are performed (the elapsed time from the point when counting the number of times of the dust removal operation commences). While the count start parameter GEN is set to 1, the value of the time count parameter GCNT is increased by the value of 1 at every predetermined time interval of 1 ms. (see step S62 in FIG. 10).

The value of the time count parameter GCNT is set to 0 (reset, see steps S17 and S20 in FIG. 4), when the value of the time count parameter GCNT exceeds 10000 (when the elapsed time, from the point when counting the number of times of the dust removal operation commences exceeds 10000 ms).

The number count parameter NUG is used for counting the number of times of the dust removal operation. The initial value of the number count parameter NUG is 0. The value of the number count parameter NUG is increased by 1 (see step S25 in FIG. 4), every dust removal operation is performed. The value of the number count parameter NUG is set to 0 (reset, see step S20 in FIG. 4), when the value of the time count parameter GCNT exceeds 10000.

The CPU **21** moves the movable unit **30a** to the predetermined position in the dust removal operation before the anti-shake operation (the centering operation, see step S84 in FIG. 7). In the embodiment, the predetermined position is the center of the range of movement (where the coordinate values in the first direction x and in the second direction y are both 0).

Then, the CPU **21** moves the movable unit **30a** in the second direction y to strike against one side of the boundary of the range of movement of the movable unit **30a** under the condition where the coordinate value in the first direction x of the movable unit **30a** is held constant at the center (a primary collision, see step S83 in FIG. 7). Next, the CPU **21** moves the movable unit **30a** in the opposite direction to strike against the other side of the boundary of the range of movement of the movable unit **30a** under the condition where the coordinate value in the first direction x of the movable unit **30a** is held constant at the center (a secondary collision, see step S82 in FIG. 7). Finally, the CPU **21** moves the movable unit **30a** again in the second direction y to strike against one side of the boundary of the range of movement of the movable unit **30a** under the condition where the coordinate value in the first direction x of the movable unit **30a** is held constant at the center (a final collision, see step S78 in FIG. 7). Namely, the movable unit **30a** strikes against the boundary of the range of movement of the movable unit **30a** (against the fixed unit **30b**) three times in total, during one dust removal operation.

The dust on the imaging unit **39a** of the movable unit **30a** (the imaging device and the low-pass filter) is removed by the shock of the impact of the movable unit **30a** against the boundary of the range of movement of the movable unit **30a**.

After the dust removal operation is complete, the anti-shake operation commences.

Specifically, in the primary collision of the dust removal operation, the movable unit **30a** is moved from the predetermined position (the center of the range of movement) to one (first) side of the boundary of the range of movement of the movable unit **30a** in the second direction y.

In the secondary collision of the dust removal operation, the movable unit **30a** is moved from one side of the boundary of the range of movement of the movable unit **30a** to the other

side of the boundary of the range of movement of the movable unit **30a** in the second direction *y*.

In the final collision of the dust removal operation, the movable unit **30a** is moved from the other side of the boundary of the range of movement of the movable unit **30a** back to the first side of the boundary of the range of movement of the movable unit **30a** in the second direction *y*.

Therefore, a force of impact in the primary collision is less than a force of impact in the secondary (and final) collision.

With the small force of impact in the primary collision, the movable unit **30a** is prepared (primed) in a condition to facilitate the ease of dust removal. Next, by the large force of impact in the secondary (or final) collision, whose force of impact is greater than that of the primary collision, the dust on the imaging unit **39a** of the movable unit **30a** is removed.

Therefore, damage to the imaging device of the imaging unit **39a** can be restrained and the dust can be removed efficiently, compared to the case where the movable unit **30a** is moved to the boundary of the range of movement of the movable unit **30a** without the centering operation.

The CPU **21** measures the continuous length of time the dust removal operations are performed (the elapsed time from the point when counting the number of times of the dust removal operation commences) and counts the number of times of the dust removal operation during the elapsed time by using the count start parameter GEN, the time count parameter GCNT, and the number count parameter NUG.

When the elapsed time is less than or equal to the third time period (10000 ms) and the number of times (cycles) of the dust removal operation is equal to or greater than the predetermined number of times (10 times), the CPU **21** halts (stops) the dust removal operation until the third time period, beginning from the point when counting the number of times of the dust removal operation commences, has elapsed. In other words, the CPU **21** resumes the dust removal operation after the third time period has elapsed (even if the number of times of the dust removal operation exceeds the predetermined number of times).

While the elapsed time is less than or equal to the third time period (10000 ms), the number of times of the dust removal operation is restricted to less than or equal to the predetermined number of times (10 times).

Further, the CPU **21** stores values of a first digital angular velocity signal Vx_n , a second digital angular velocity signal Vy_n , a first digital angular velocity VVx_n , a second digital angular velocity VVy_n , a digital displacement angle Bx_n , a second digital displacement angle By_n , a coordinate of position S_n in the first direction *x*: Sx_n , a coordinate of position S_n in the second direction *y*: Sy_n , a first driving force Dx_n , a second driving force Dy_n , a coordinate of position P_n after A/D conversion in the first direction *x*: pdx_n , a coordinate of position P_n after A/D conversion in the second direction *y*: pdy_n , a first subtraction value ex_n , a second subtraction value ey_n , a first proportional coefficient Kx , a second proportional coefficient Ky , a sampling cycle θ of the anti-shake operation, a first integral coefficient Tix , a second integral coefficient Tiy , a first differential coefficient Tdx , and a second differential coefficient Tdy .

The AE unit (an exposure calculating unit) **23** performs the photometric operation and calculates the photometric values, based on the subject being photographed. The AE unit **23** also calculates the aperture value and the time length of the exposure, with respect to the photometric values, both of which are needed for imaging. The AF unit **24** performs the AF sensing operation and the corresponding focusing operation, both of

which are needed for imaging. In the focusing operation, the camera lens **67** is re-positioned along the optical axis in the LX direction.

The anti-shake part (the anti-shake apparatus) of the photographing apparatus **1** comprises an anti-shake button **14**, an anti-shake switch **14a**, an indicating unit **17**, a CPU **21**, an angular velocity detection unit **25**, a driver circuit **29**, an anti-shake unit **30**, a hall-element signal-processing unit **45** (a magnetic-field change-detecting element), and the camera lens **67**.

When the anti-shake button **14** is depressed by the operator, the anti-shake switch **14a** is changed to the ON state so that the anti-shake operation, in which the angular velocity detection unit **25** and the anti-shake unit **30** are driven independently of the other operations which include the photometric operation etc., is carried out at every predetermined time interval of 1 ms. When the anti-shake switch **14a** is in the ON state, in other words in the anti-shake mode, the anti-shake parameter IS is set to 1 (IS=1). When the anti-shake switch **14a** is not in the ON state, in other words in the non-anti-shake mode, the anti-shake parameter IS is set to 0 (IS=0).

The various output commands corresponding to the input signals of these switches are controlled by the CPU **21**.

The information regarding whether the photometric switch **12a** is in the ON state or OFF state is input to port P12 of the CPU **21** as a 1-bit digital signal. The information regarding whether the release switch **13a** is in the ON state or OFF state is input to port P13 of the CPU **21** as a 1-bit digital signal. The information regarding whether the anti-shake switch **14a** is in the ON state or OFF state is input to port P14 of the CPU **21** as a 1-bit digital signal. The information regarding whether the dust removal switch **15a** is in the ON state or OFF state is input to port P15 of the CPU **21** as a 1-bit digital signal.

The AE unit **23** is connected to port P4 of the CPU **21** for inputting and outputting signals. The AF unit **24** is connected to port P5 of the CPU **21** for inputting and outputting signals. The indicating unit **17** is connected to port P6 of the CPU **21** for inputting and outputting signals.

Next, the details of the input and output relationships between the CPU **21** and the angular velocity detection unit **25**, the driver circuit **29**, the anti-shake unit **30**, and the hall-element signal-processing unit **45** are explained.

The angular velocity detection unit **25** has a first angular velocity sensor **26a**, a second angular velocity sensor **26b**, a first high-pass filter circuit **27a**, a second high-pass filter circuit **27b**, a first amplifier **28a** and a second amplifier **28b**.

The first angular velocity sensor **26a** detects the angular velocity of a rotary motion (the yawing) of the photographing apparatus **1** about the axis of the second direction *y* (the velocity-component in the first direction *x* of the angular velocity of the photographing apparatus **1**). The first angular velocity sensor **26a** is a gyro sensor that detects a yawing angular velocity.

The second angular velocity sensor **26b** detects the angular velocity of a rotary motion (the pitching) of the photographing apparatus **1** about the axis of the first direction *x* (detects the velocity-component in the second direction *y* of the angular velocity of the photographing apparatus **1**). The second angular velocity sensor **26b** is a gyro sensor that detects a pitching angular velocity.

The first high-pass filter circuit **27a** reduces a low frequency component of the signal output from the first angular velocity sensor **26a**, because the low frequency component of the signal output from the first angular velocity sensor **26a** includes signal elements that are based on a null voltage and a panning-motion, neither of which are related to hand-shake.

The second high-pass filter circuit **27b** reduces a low frequency component of the signal output from the second angular velocity sensor **26b**, because the low frequency component of the signal output from the second angular velocity sensor **26b** includes signal elements that are based on a null voltage and a panning-motion, neither of which are related to hand-shake.

The first amplifier **28a** amplifies a signal regarding the yawing angular velocity, whose low frequency component has been reduced, and outputs the analog signal to the A/D converter A/D **0** of the CPU **21** as a first angular velocity v_x .

The second amplifier **28b** amplifies a signal regarding the pitching angular velocity, whose low frequency component has been reduced, and outputs the analog signal to the A/D converter A/D **1** of the CPU **21** as a second angular velocity v_y .

The reduction of the low frequency signal component is a two-step process; the primary part of the analog high-pass filter processing operation is performed first by the first and second high-pass filter circuits **27a** and **27b**, followed by the secondary part of the digital high-pass filter processing operation that is performed by the CPU **21**.

The cut-off frequency of the secondary part of the digital high-pass filter processing operation is higher than that of the primary part of the analog high-pass filter processing operation.

In the digital high-pass filter processing operation, the value of a time constant (a first high-pass filter time constant h_x and a second high-pass filter time constant h_y) can be easily changed.

The supply of electric power to the CPU **21** and each part of the angular velocity detection unit **25** begins after the PON switch **11a** is set to the ON state (the main power supply is set to the ON state). The calculation of a hand-shake quantity begins after the PON switch **11a** is set to the ON state.

The CPU **21** converts the first angular velocity v_x , which is input to the A/D converter A/D **0**, to a first digital angular velocity signal Vx_n (A/D conversion operation); calculates a first digital angular velocity VVx_n by reducing a low frequency component of the first digital angular velocity signal Vx_n (the digital high-pass filter processing operation) because the low frequency component of the first digital angular velocity signal Vx_n includes signal elements that are based on a null voltage and a panning-motion, neither of which are related to hand-shake; and calculates a hand shake quantity (a hand shake displacement angle: a first digital displacement angle Bx_n) by integrating the first digital angular velocity VVx_n (the integration processing operation).

Similarly, the CPU **21** converts the second angular velocity v_y , which is input to the A/D converter A/D **1**, to a second digital angular velocity signal Vy_n (A/D conversion operation); calculates a second digital angular velocity VVy_n by reducing a low frequency component of the second digital angular velocity signal Vy_n (the digital high-pass filter processing operation) because the low frequency component of the second digital angular velocity signal Vy_n includes signal elements that are based on a null voltage and a panning-motion, neither of which are related to hand-shake; and calculates a hand shake quantity (a hand shake displacement angle: a second digital displacement angle By_n) by integrating the second digital angular velocity VVy_n (the integration processing operation).

Accordingly, the CPU **21** and the angular velocity detection unit **25** use a function to calculate the hand-shake quantity.

“n” is an integer that is greater than 0 and indicates a length of time (ms) from the commencement of the first and second

interruption processes of the timer, ($t=0$; see step S12 in FIG. **4**) to the point when the latest anti-shake operation is performed (the first and second interruption processes of the timer are performed) ($t=n$).

In the digital high-pass filter processing operation regarding the first direction x, the first digital angular velocity VVx_n is calculated by dividing the summation of the first digital angular velocity VVx_0 to VVx_{n-1} calculated by the first interruption process of the timer before the predetermined time interval of 1 ms (before the latest anti-shake operation is performed), by the first high-pass-filter time constant h_x , and then subtracting the resulting quotient from the first digital angular velocity signal Vx_n ($VVx_n = Vx_n - (\sum VVx_{n-1}) \div h_x$, see (1) in FIG. **6**).

In the digital high-pass filter processing operation regarding the second direction y, the second digital angular velocity VVy_n is calculated by dividing the summation of the second digital angular velocity VVy_0 to VVy_{n-1} calculated by the first interruption process of the timer before the predetermined time interval of 1 ms (before the latest anti-shake operation is performed), by the second high-pass filter time constant h_y , and then subtracting the resulting quotient from the second digital angular velocity signal Vy_n ($VVy_n = Vy_n - (\sum VVy_{n-1}) \div h_y$).

In the embodiment, the angular velocity detection operation in (portion of) the first interruption process of the timer includes a process in the angular velocity detection unit **25** and a process of inputting the first and second angular velocities v_x and v_y from the angular velocity detection unit **25** to the CPU **21**.

In the integration processing operation regarding the first direction x, the first digital displacement angle Bx_n is calculated by the summation from the first digital angular velocity VVx_0 at the point when the first interruption process of the timer commences, $t=0$, (see step S12 in FIG. **4**) to the first digital angular velocity VVx_n at the point when the latest anti-shake operation is performed ($t=n$), ($Bx_n = \sum VVx_n$, see (3) in FIG. **6**).

Similarly, in the integration processing operation regarding the second direction y, the second digital displacement angle By_n is calculated by the summation from the second digital angular velocity VVy_0 at the point when the first interruption process of the timer commences to the second digital angular velocity VVy_n at the point when the latest anti-shake operation is performed ($By_n = \sum VVy_n$).

The CPU **21** calculates the position S_n where the imaging unit **39a** (the movable unit **30a**) should be moved, corresponding to the hand-shake quantity (the first and second digital displacement angles Bx_n and By_n) that is calculated for the first direction x and the second direction y on the basis of a position conversion coefficient zz (a first position conversion coefficient zx for the first direction x and a second position conversion coefficient zy for the second direction y).

The coordinate of position S_n in the first direction x is defined as Sx_n , and the coordinate of position S_n in the second direction y is defined as Sy_n . The movement of the movable unit **30a**, which includes the imaging unit **39a**, is performed by using electro-magnetic force and is described later.

The driving force D_n drives the driver circuit **29** in order to move the movable unit **30a** to the position S_n . The coordinate of the driving force D_n in the first direction x is defined as the first driving force $D \times n$ (after D/A conversion: a first PWM duty dx). The coordinate of the driving force D_n in the second direction y is defined as the second driving force Dy_n (after D/A conversion: a second PWM duty dy).

The first PWM duty dx is a duty ratio of the driving pulse corresponding to the first driving force Dx_n . The second

PWM duty dy is a duty ratio of the driving pulse corresponding to the second driving force Dy_n .

However, the position S_n where the imaging unit **39a** (the movable unit **30a**) should be moved in the first time period (220 ms) for the dust removal operation before the anti-shake operation is performed, is set to a value that does not correspond to the hand-shake quantity (see step **S79** in FIG. 7).

In a positioning operation regarding the first direction x , the coordinate of position S_n in the first direction x is defined as Sx_n , and is the product of the latest first digital displacement angle Bx_n and the first position conversion coefficient zx ($Sx_n = zx \times Bx_n$, see (3) in FIG. 6).

In a positioning operation regarding the second direction y , the coordinate of position S_n in the second direction y is defined as Sy_n , and is the product of the latest second digital displacement angle By_n and the second position conversion coefficient zy ($Sy_n = zy \times By_n$).

The anti-shake unit **30** is an apparatus that corrects for the hand-shake effect by moving the imaging unit **39a** to the position S_n , by canceling the lag of the photographing subject image on the imaging surface of the imaging device of the imaging unit **39a**, and by stabilizing the photographing subject image displayed on the imaging surface of the imaging device during the exposure time when the anti-shake operation is performed ($IS=1$).

The anti-shake unit **30** has a fixed unit **30b** that forms the boundary of the range of movement of the movable unit **30a**, and a movable unit **30a** which includes the imaging unit **39a** and can be moved about on the xy plane that is parallel to the first direction x and the second direction y .

During the exposure time when the anti-shake operation is not performed ($IS=0$), the movable unit **30a** is fixed to (held in) the predetermined position (at the center of the range of movement).

In the first time period (220 ms) after the photographing apparatus **1** is set to the ON state, the movable unit **30a** is driven to the predetermined position that is the center of the range of movement. Next, the movable unit **30a** is driven to (is struck against) the boundary of the range of movement in the second direction y .

Otherwise (except for the first time period and the exposure time), the movable unit **30a** is not driven (moved).

The anti-shake unit **30** does not have a fixed-positioning mechanism that maintains the movable unit **30a** in a fixed position when the movable unit **30a** is not being driven (drive OFF state).

The driving of the movable unit **30a** of the anti-shake unit **30**, including movement to a predetermined fixed (held) position, is performed by the electromagnetic force of the coil unit for driving and the magnetic unit for driving, through the driver circuit **29** which has the first PWM duty dx input from the PWM **0** of the CPU **21** and has the second PWM duty dy input from the PWM **1** of the CPU **21** (see (5) in FIG. 6).

The detected position P_n of the movable unit **30a**, either before or after the movement effected by the driver circuit **29**, is detected by the hall element unit **44a** and the hall-element signal-processing unit **45**.

Information regarding the first coordinate of the detected position P_n in the first direction x , in other words a first detected position signal px , is input to the A/D converter A/D **2** of the CPU **21** (see (2) in FIG. 6). The first detected position signal px is an analog signal that is converted to a digital signal by the A/D converter A/D **2** (A/D conversion operation). The first coordinate of the detected position P_n in the first direction x , after the A/D conversion operation, is defined as pdx_n and corresponds to the first detected position signal px .

Information regarding the second coordinate of the detected position P_n in the second direction y , in other words a second detected position signal py , is input to the A/D converter A/D **3** of the CPU **21**. The second detected position signal py is an analog signal that is converted to a digital signal by the A/D converter A/D **3** (A/D conversion operation). The second coordinate of the detected position P_n in the second direction y , after the A/D conversion operation, is defined as $pdyn$ and corresponds to the second detected position signal py .

The PID (Proportional Integral Differential) control calculates the first and second driving forces Dx_n and Dy_n on the basis of the coordinate data for the detected position P_n (pdx_n , $pdyn$) and the position S_n (Sx_n , Sy_n) following movement.

The calculation of the first driving force Dx_n is based on the first subtraction value ex_n , the first proportional coefficient Kx , the sampling cycle θ , the first integral coefficient Tix , and the first differential coefficient Tdx ($Dx_n = Kx \times \{ex_n + \theta + Tix \times \Sigma ex_n + Tdx + \theta \times (ex_n - ex_{n-1})\}$, see (4) in FIG. 6). The first subtraction value ex_n is calculated by subtracting the first coordinate of the detected position P_n in the first direction x after the A/D conversion operation, pdx_n , from the coordinate of position S_n in the first direction x , Sx_n ($ex_n = Sx_n - pdx_n$).

The calculation of the second driving force Dy_n is based on the second subtraction value ey_n , the second proportional coefficient Ky , the sampling cycle θ , the second integral coefficient Tiy , and the second differential coefficient Tdy ($Dy_n = Ky \times \{ey_n + \theta + Tiy \times \Sigma ey_n + Tdy + \theta \times (ey_n - ey_{n-1})\}$). The second subtraction value ey_n is calculated by subtracting the second coordinate of the detected position P_n in the second direction y after the A/D conversion operation, $pdyn$, from the coordinate of position S_n in the second direction y , Sy_n ($ey_n = Sy_n - pdyn$).

The value of the sampling cycle θ is set to the predetermined time interval of 1 ms.

Driving the movable unit **30a** to the position S_n , (Sx_n, Sy_n) corresponding to the anti-shake operation of the PID control, is performed when the photographing apparatus **1** is in the anti-shake mode ($IS=1$) where the anti-shake switch **14a** is set to the ON state.

When the anti-shake parameter IS is 0, the PID control that does not correspond to the anti-shake operation is performed so that the movable unit **30a** is moved to the center of the range of movement (the predetermined position).

In the dust removal operation, from the point when the photographing apparatus **1** is set to the ON state until the anti-shake operation commences, the movable unit **30a** is first moved to the center of the range of movement, then moved to one side of the boundary of the range of movement in the second direction y (the primary collision), then moved to the opposite side of the boundary of the range of movement in the second direction y (the secondary collision), then moved again to the original side of the boundary of the range of movement in the second direction y (the final collision), in order. In this period, the coordinate of the movable unit **30a** in the first direction x is held constant at the center.

The movable unit **30a** has a coil unit for driving that is comprised of a first driving coil **31a** and a second driving coil **32a**, an imaging unit **39a** that has the imaging device, and a hall element unit **44a** as a magnetic-field change-detecting element unit. In the embodiment, the imaging device is a CCD; however, the imaging device may be another imaging device such as a CMOS etc.

A rectangle shape, which is the form of the imaging surface of the imaging device, has two sides that are parallel to the first direction x and has two sides that are parallel to the second direction y and that are shorter than the two sides

11

parallel to the first direction x , under the condition where the control of movement of the movable unit **30a** is not performed.

Accordingly, the range of movement of the movable unit **30a** in the first direction x is longer (wider) than that in the second direction y .

The fixed unit **30b** has a magnetic unit for driving that is comprised of a first position-detecting and driving magnet **411b**, a second position-detecting and driving magnet **412b**, a first position-detecting and driving yoke **431b**, and a second position-detecting and driving yoke **432b**.

The fixed unit **30b** movably supports the movable unit **30a** in the first direction x and in the second direction y .

The fixed unit **30b** has a buffer member that absorbs the shock at the point of contact with the movable unit **30a** (at the boundary of the range of movement).

The hardness of the buffer member is set so that the part making contact, such as the movable unit **30a** etc., is not damaged by the shock of the impact, and the dust on the movable unit **30a** is removed by the shock of the impact, when the movable unit **30a** is moved to the boundary of the range of movement of the movable unit **30a** and struck against the fixed unit **30b** through the buffer member.

In the embodiment, the buffer member is attached to the fixed unit **30b**, however, the buffer member may be attached to the movable unit **30a**.

When the center area of the imaging device intersects by the optical axis LX of the camera lens **67**, the relationship between the position of the movable unit **30a** and the position of the fixed unit **30b** is arranged so that the movable unit **30a** is positioned at the center of its range of movement in both the first direction x and the second direction y , in order to utilize the full size of the imaging range of the imaging device.

The rectangle shape, which is the form of the imaging surface of the imaging device, has two diagonal lines. In the embodiment, the center of the imaging device is at the intersection of these two diagonal lines.

The first driving coil **31a**, the second driving coil **32a**, and the hall element unit **44a** are attached to the movable unit **30a**.

The first driving coil **31a** forms a seat and a spiral shaped coil pattern. The coil pattern of the first driving coil **31a** has lines which are parallel to the second direction y , thus creating the first electro-magnetic force to move the movable unit **30a** that includes the first driving coil **31a**, in the first direction x .

The first electro-magnetic force occurs on the basis of the current direction of the first driving coil **31a** and the magnetic-field direction of the first position-detecting and driving magnet **411b**.

The second driving coil **32a** forms a seat and a spiral shaped coil pattern. The coil pattern of the second driving coil **32a** has lines which are parallel to the first direction x , thus creating the second electro-magnetic force to move the movable unit **30a** that includes the second driving coil **32a**, in the second direction y .

The second electromagnetic force occurs on the basis of the current direction of the second driving coil **32a** and the magnetic-field direction of the second position-detecting and driving magnet **412b**.

The first and second driving coils **31a** and **32a** are connected to the driver circuit **29**, which drives the first and second driving coils **31a** and **32a**, through the flexible circuit board (not depicted). The first PWM duty dx is input to the driver circuit **29** from the PWM **0** of the CPU **21**, and the second PWM duty dy is input to the driver circuit **29** from the PWM **1** of the CPU **21**. The driver circuit **29** supplies power to the first driving coil **31a** that corresponds to the value of the

12

first PWM duty dx , and to the second driving coil **32a** that corresponds to the value of the second PWM duty dy , to drive the movable unit **30a**.

The first position-detecting and driving magnet **411b** is attached to the movable unit side of the fixed unit **30b**, where the first position-detecting and driving magnet **411b** faces the first driving coil **31a** and the horizontal hall element $hh10$ in the third direction z .

The second position-detecting and driving magnet **412b** is attached to the movable unit side of the fixed unit **30b**, where the second position-detecting and driving magnet **412b** faces the second driving coil **32a** and the vertical hall element $hv10$ in the third direction z .

The first position-detecting and driving magnet **411b** is attached to the first position-detecting and driving yoke **431b**, under the condition where the N pole and S pole are arranged in the first direction x . The first position-detecting and driving yoke **431b** is attached to the fixed unit **30b** on the side of the movable unit **30a** in the third direction z .

The second position-detecting and driving magnet **412b** is attached to the second position-detecting and driving yoke **432b**, under the condition where the N pole and S pole are arranged in the second direction y . The second position-detecting and driving yoke **432b** is attached to the fixed unit **30b** on the side of the movable unit **30a** in the third direction z .

The first and second position-detecting and driving yokes **431b**, **432b** are made of a soft magnetic material.

The first position-detecting and driving yoke **431b** prevents the magnetic-field of the first position-detecting and driving magnet **411b** from dissipating to the surroundings, and raises the magnetic-flux density between the first position-detecting and driving magnet **411b** and the first driving coil **31a**, and between the first position-detecting and driving magnet **411b** and the horizontal hall element $hh10$.

The second position-detecting and driving yoke **432b** prevents the magnetic-field of the second position-detecting and driving magnet **412b** from dissipating to the surroundings, and raises the magnetic-flux density between the second position-detecting and driving magnet **412b** and the second driving coil **32a**, and between the second position-detecting and driving magnet **412b** and the vertical hall element $hv10$.

The hall element unit **44a** is a single-axis unit that contains two magnetoelectric converting elements (magnetic-field change-detecting elements) utilizing the Hall Effect to detect the first detected position signal px and the second detected position signal py specifying the first coordinate in the first direction x and the second coordinate in the second direction y , respectively, of the present position P_n of the movable unit **30a**.

One of the two hall elements is a horizontal hall element $hh10$ for detecting the first coordinate of the position P_n of the movable unit **30a** in the first direction x , and the other is a vertical hall element $hv10$ for detecting the second coordinate of the position P_n of the movable unit **30a** in the second direction y .

The horizontal hall element $hh10$ is attached to the movable unit **30a**, where the horizontal hall element $hh10$ faces the first position-detecting and driving magnet **411b** of the fixed unit **30b** in the third direction z .

The vertical hall element $hv10$ is attached to the movable unit **30a**, where the vertical hall element $hv10$ faces the second position-detecting and driving magnet **412b** of the fixed unit **30b** in the third direction z .

When the center of the imaging device intersects the optical axis LX , it is desirable to have the horizontal hall element $hh10$ positioned on the hall element unit **44a** facing an intermediate area between the N pole and S pole of the first

13

position-detecting and driving magnet **411b** in the first direction *x*, as viewed from the third direction *z*. In this position, the horizontal hall element **hh10** utilizes the maximum range in which an accurate position-detecting operation can be performed based on the linear output-change (linearity) of the single-axis hall element.

Similarly, when the center of the imaging device intersects the optical axis *LX*, it is desirable to have the vertical hall element **hv10** positioned on the hall element unit **44a** facing an intermediate area between the N pole and S pole of the second position-detecting and driving magnet **412b** in the second direction *y*, as viewed from the third direction *z*.

The hall-element signal-processing unit **45** has a first hall-element signal-processing circuit **450** and a second hall-element signal-processing circuit **460**.

The first hall-element signal-processing circuit **450** detects a horizontal potential-difference **x10** between the output terminals of the horizontal hall element **hh10** that is based on an output signal of the horizontal ha11 element **hh10**.

The first hall-element signal-processing circuit **450** outputs the first detected position signal **px**, which specifies the first coordinate of the position P_n of the movable unit **30a** in the first direction *x*, to the A/D converter A/D **2** of the CPU **21**, on the basis of the horizontal potential-difference **x10**.

The second hall-element signal-processing circuit **460** detects a vertical potential-difference **y10** between the output terminals of the vertical hall element **hv10** that is based on an output signal of the vertical hall element **hv10**.

The second hall-element signal-processing circuit **460** outputs the second detected position signal **py**, which specifies the second coordinate of the position P_n of the movable unit **30a** in the second direction *y*, to the A/D converter A/D **3** of the CPU **21**, on the basis of the vertical potential-difference **y10**.

Next, the main operation of the photographing apparatus **1** in the embodiment is explained by using the flowchart in FIG. **4**.

When the photographing apparatus **1** is set to the ON state, the electrical power is supplied to the angular velocity detection unit **25** so that the angular velocity detection unit **25** is set to the ON state in step **S11**.

In step **S12**, the first and second interruption processes of the timer commence at the predetermined time interval (1 ms). In step **S13**, the value of the release state parameter **RP** is set to 0. The detail of the first interruption process of the timer is explained later by using the flowchart in FIG. **5**. The detail of the second interruption process of the timer is explained later by using the flowchart in FIG. **10**.

In step **S14**, the value of the count start parameter **GEN**, the value of the time count parameter **GCNT**, the number count parameter **NUG**, and the value of the dust removal state parameter **GP** is set to 0.

In step **S15**, it is determined whether the value of the dust removal switch **15a** is set to the ON state. When it is determined that the value of the dust removal switch **15a** is set to the ON state, the operation proceeds directly to step **S18**; otherwise, the operation continues to step **S16**.

In step **S16**, it is determined whether the value of the time count parameter **GCNT** is greater than 10000. When it is determined that the value of the time count parameter **GCNT** is greater than 10000, the operation continues to step **S17**; otherwise, the operation proceeds directly to step **S26**.

In step **S17**, the value of the count start parameter **GEN**, the value of the time count parameter **GCNT**, and the value of the number count parameter **NUG** are set to 0.

In step **S18**, it is determined whether the value of the time count parameter **GCNT** is greater than 10000. When it is

14

determined that the value of the time count parameter **GCNT** is greater than 10000, the operation proceeds directly to step **S20**; otherwise, the operation continues to step **S19**.

In step **S19**, it is determined whether the value of the number count parameter **NUG** is greater than 10. When it is determined that the value of the number count parameter **NUG** is greater than 10, the operation proceeds directly to step **S26**; otherwise, the operation proceeds directly to step **S21**.

In other words, when the value of the number count parameter **NUG** exceeds 10 (the number of times (cycles) of the dust removal operation is equal to or greater than the predetermined number of times (10 times)) before the third time period (10000 ms) has elapsed, the operation proceeds directly to step **S26** (not through steps **S21** and **S22**). In this case, because both the value of the count start parameter **GEN** and the value of the dust removal state parameter **GP** are 0, the dust removal operation is not performed (the operation does not proceed to step **S51** in FIG. **5**) even if the first or second interruption process of the timer commences. Therefore, the dust removal operation is halted until the third time period, beginning from the point when counting the number of times of the dust removal operation commences, has elapsed.

In step **S20**, the value of the time count parameter **GCNT** and the value of the number count parameter **NUG** are set to 0. In step **S21**, the value of the count start parameter **GEN** is set to 1.

In step **S22**, the value of the dust removal state parameter **GP** is set to 1 and the value of the dust removal time parameter **CNT** is set to 0.

In step **S23**, it is determined whether the value of the dust removal time parameter **CNT** is greater than 220. When it is determined that the value of the dust removal time parameter **CNT** is greater than 220, the operation continues to step **S24**; otherwise, the operation in step **S23** is repeated.

In step **S24**, the value of the dust removal state parameter **GP** is set to 0.

In step **S25**, the value of the number count parameter **NUG** is increased by 1 and the operation continues to step **S26**.

In step **S26**, it is determined whether the photometric switch **12a** is set to the ON state. When it is determined that the photometric switch **12a** is set to the ON state, the operation continues to step **S27**; otherwise, the operation returns to step **S15**.

In step **S27**, it is determined whether the anti-shake switch **14a** is set to the ON state. When it is determined that the anti-shake switch **14a** is not set to the ON state, the value of the anti-shake parameter **IS** is set to 0 in step **S28**; otherwise, the value of the anti-shake parameter **IS** is set to 1 in step **S29**.

In step **S30**, the AE sensor of the AE unit **23** is driven, the photometric operation is performed, and the aperture value and exposure time are calculated.

In step **S31**, the AF sensor and the lens control circuit of the AF unit **24** are driven to perform the AF sensing and focus operations, respectively.

In step **S32**, it is determined whether the release switch **13a** is set to the ON state. When the release switch **13a** is not set to the ON state, the operation returns to step **S15** and the process in steps **S15** to **S31** is repeated; otherwise, the operation continues on to step **S33** and the release sequence operation commences.

In step **S33**, the value of the release state parameter **RP** is set to 1. In step **S34**, the mirror-up operation and the aperture closing operation corresponding to the aperture value that is either preset or calculated, are performed by the mirror-aperture-shutter unit **18**.

After the mirror-up operation is finished, the opening operation of the shutter (the movement of the front curtain in the shutter) commences, in step S35.

In step S36, the exposure operation, or in other words the electric charge accumulation of the imaging device (CCD etc.), is performed. After the exposure time has elapsed, the closing operation of the shutter (the movement of the rear curtain in the shutter), the mirror-down operation, and the opening operation of the aperture are performed by the mirror-aperture-shutter unit 18 in step S37.

In step S38, the electric charge which has accumulated in the imaging device during the exposure time is read. In step S39, the CPU 21 communicates with the DSP 19 so that the image processing operation is performed based on the electric charge read from the imaging device. The image, on which the image processing operation is performed, is stored to the memory in the photographing apparatus 1. In step S40, the image that is stored in the memory is displayed on the indicating unit 17. In step S41, the value of the release state parameter RP is set to 0 so that the release sequence operation is finished, and the operation then returns to step S15. In other words, the photographing apparatus 1 is set to a state where the next imaging operation can be performed.

Next, the first interruption process of the timer, which commences in step S12 in FIG. 4 and is performed at every predetermined time interval (1 ms) independent of the other operations, is explained by using the flowchart in FIG. 5.

When the first interruption process of the timer commences, it is determined whether the value of the dust removal state parameter GP is set to 1, in step S50. When it is determined that the value of the dust removal state parameter GP is set to 1, the operation continues to step S51; otherwise, the operation proceeds directly to step S52.

In step S51, the dust removal operation is performed. The detail of the dust removal operation is explained later by using the flowchart in FIG. 7.

In step S52, the first angular velocity v_x , which is output from the angular velocity detection unit 25, is input to the A/D converter A/D 0 of the CPU 21 and converted to the first digital angular velocity signal V_{x_n} . The second angular velocity v_y , which is also output from the angular velocity detection unit 25, is input to the A/D converter A/D 1 of the CPU 21 and converted to the second digital angular velocity signal V_{y_n} (the angular velocity detection operation).

The low frequencies of the first and second digital angular velocity signals V_{x_n} and V_{y_n} are reduced in the digital high-pass filter processing operation (the first and second digital angular velocities VV_{x_n} and VV_{y_n}).

In step S53, it is determined whether the value of the release state parameter RP is set to 1. When it is determined that the value of the release state parameter RP is not set to 1, the driving control of the movable unit 30a is set to the OFF state, in other words, the anti-shake unit 30 is set to a state where the driving control of the movable unit 30a is not performed in step S54; otherwise, the operation proceeds directly to step S55.

In step S55, the hall element unit 44a detects the position of the movable unit 30a, and the first and second detected position signals p_x and p_y are calculated by the hall-element signal-processing unit 45. The first detected position signal p_x is then input to the A/D converter A/D 2 of the CPU 21 and converted to a digital signal pdx_n , whereas the second detected position signal p_y is input to the A/D converter A/D 3 of the CPU 21 and also converted to a digital signal $pdyn$, both of which thus determine the present position P_n (pdx_n , $pdyn$) of the movable unit 30a.

In step S56, it is determined whether the value of the anti-shake parameter IS is 0. When it is determined that the value of the anti-shake parameter IS is 0 (IS=0), in other words when the photographing apparatus is not in anti-shake mode, the position S (Sx_n , Sy_n) where the movable unit 30a (the imaging unit 39a) should be moved is set at the center of the range of movement of the movable unit 30a, in step S57. When it is determined that the value of the anti-shake parameter IS is not 0 (IS=1), in other words when the photographing apparatus is in anti-shake mode, the position S_n (Sx_n , Sy_n) where the movable unit 30a (the imaging unit 39a) should be moved is calculated on the basis of the first and second angular velocities v_x and v_y , in step S58.

In step S59, the first driving force Dx_n (the first PWM duty dx) and the second driving force Dy_n (the second PWM duty dy) of the driving force D_n that moves the movable unit 30a to the position S_n are calculated on the basis of the position S_n (Sx_n , Sy_n) that was determined in step S57 or step S58, and the present position P_n (pdx_n , $pdyn$).

In step S60, the first driving coil unit 31a is driven by applying the first PWM duty dx to the driver circuit 29, and the second driving coil unit 32a is driven by applying the second PWM duty dy to the driver circuit 29, so that the movable unit 30a is moved to position S_n (Sx_n , Sy_n).

The process of steps S59 and S60 is an automatic control calculation that is used with the PID automatic control for performing general (normal) proportional, integral, and differential calculations.

Next, the dust removal operation, which commences in step S51 in FIG. 5, is explained by using the flowchart in FIG. 7.

When the dust removal operation commences, the value of the dust removal time parameter CNT is increased by 1, in step S71.

In step S72, the hall element unit 44a detects the position of the movable unit 30a, and the first and second detected position signals p_x and p_y are calculated by the hall-element signal-processing unit 45. The first detected position signal p_x is then input to the A/D converter A/D 2 of the CPU 21 and converted to a digital signal pdx_n , whereas the second detected position signal p_y is input to the A/D converter A/D 3 of the CPU 21 and also converted to a digital signal $pdyn$, both of which thus determine the present position P_n (pdx_n , $pdyn$) of the movable unit 30a.

In step S73, it is determined whether the value of the dust removal time parameter CNT is less than or equal to 65. When it is determined that the value of the dust removal time parameter CNT is less than or equal to 65, the operation proceeds directly to step S84; otherwise, the operation continues to step S74.

In step S74, it is determined whether the value of the dust removal time parameter CNT is less than or equal to 115. When it is determined that the value of the dust removal time parameter CNT is less than or equal to 115, the operation proceeds directly to step S83; otherwise, the operation continues to step S75.

In step S75, it is determined whether the value of the dust removal time parameter CNT is less than or equal to 165. When it is determined that the value of the dust removal time parameter CNT is less than or equal to 165, the operation proceeds directly to step S82; otherwise, the operation continues to step S76.

In step S76, it is determined whether the value of the dust removal time parameter CNT is less than or equal to 215. When it is determined that the value of the dust removal time

parameter CNT is less than or equal to 215, the operation proceeds directly to step S78; otherwise, the operation continues to step S77.

In step S77, the driving control of the movable unit 30a is set to the OFF state, in other words, the anti-shake unit 30 is set to a state where the driving control of the movable unit 30a is not performed.

In steps S78 and S83, the value of the second PWM duty dy is set to -DD. In step S82, the value of the second PWM duty dy is set to +DD.

The absolute value |DD| (the absolute value of a dust removal duty ratio DD) is set so that the acceleration of the movable unit 30a at point in time when the movable unit 30a is moved to and struck against the boundary of the range of movement of the movable unit 30a is increased to the degree where the dust on the movable unit 30a can be removed by the shock of the impact.

In step S79, the coordinate of position S_n in the first direction x, Sx_n , where the movable unit 30a (the imaging unit 39a) should be moved in the first direction x is set at the center of the range of movement of the movable unit 30a in the first direction x.

In step S80, the first driving force Dx_n (the first PWM duty dx) of the driving force D_n that moves (holds) the movable unit 30a to the position S_n in the first direction x (the center in the first direction x), is calculated on the basis of the coordinate of position S_n in the first direction x, Sx_n , that was determined in step S79, and the coordinate of the present position P_n after A/D conversion in the first direction x: pdx_n .

In step S81, the first driving coil unit 31a is driven by applying the first PWM duty dx calculated in step S80 to the driver circuit 29, and the second driving coil unit 32a is driven by applying the second PWM duty dy calculated in step S78, S82, or S83 to the driver circuit 29, so that the movable unit 30a is moved to position S_n (Sx_n, Sy_n).

In step S84, the position S_n (Sx_n, Sy_n) where the movable unit 30a (the imaging unit 39a) should be moved is set at the center of the range of movement of the movable unit 30a.

In step S85, the first driving force Dx_n (the first PWM duty dx) and the second driving force Dy_n (the second PWM duty dy) of the driving force D_n that moves the movable unit 30a to the position S_n , are calculated on the basis of the position S_n (Sx_n, Sy_n) that was determined in step S84, and the present position P_n (pdx_n, pdy_n).

In step S86, the first driving coil unit 31a is driven by applying the first PWM duty dx to the driver circuit 29 calculated in step S85, and the second driving coil unit 32a is driven by applying the second PWM duty dy to the driver circuit 29 calculated in step S85, so that the movable unit 30a is moved to position S_n (Sx_n, Sy_n).

Next, the second interruption process of the timer, which commences in step S12 in FIG. 4 and is performed at every predetermined time interval (1 ms) independent of the other operations, is explained by using the flowchart in FIG. 10.

When the second interruption process of the timer commences, it is determined whether the value of the count start parameter GEN is set to 1. When it is determined that the value of the count start parameter GEN is set to 1, the value of the time count parameter GCNT is increased by 1 in step S62, and then the second interruption process of the timer is finished; otherwise, the second interruption process of the timer is finished without operation.

In the embodiment, in the first time period, from the point when the photographing apparatus 1 is set to the ON state to the point when the anti-shake operation commences, the movable unit 30a including the imaging device is moved to the center and then is moved to and struck against one side and

then the other side of the boundary of the range of movement of the movable unit 30a, under the condition where the coordinate value in the first direction x of the movable unit 30a is held constant at the center (see FIGS. 8 and 9).

The dust on the imaging unit 39a of the movable unit 30a (the imaging device and the low-pass filter) can be removed by the shock of the impact of the movable unit 30a against the boundary of the range of movement of the movable unit 30a.

In the dust removal operation, the position of the movable unit 30a in the first direction x is held constant at the center of the range of movement in the first direction x. Accordingly, the movable unit 30a in the first direction x does not make contact with the boundary of the range of movement in the first direction x, while the movable unit 30a is moved in the second direction y. As a result, the movable unit 30a and the fixed unit 30b are not damaged.

The dust removal operation may be halted in a predetermined time period (for example 10 sec) as another embodiment; however, in the embodiment, the continuous length of time the dust removal operations are performed (the elapsed time from the point when counting the number of times of the dust removal operation commences) is measured and the number of times of the dust removal operation during the elapsed time is counted so that the dust removal operation is halted when the elapsed time is less than or equal to the third time period (10000 ms), and when the number of times of the dust removal operation is equal to or exceeds the predetermined number of times (10 times).

Therefore, the number of times that the movable unit 30a is struck against the boundary of the range of movement of the movable unit 30a in a short time period (the third time period) for the dust removal operation can be limited, in order to prevent damage to the movable unit 30a etc. caused by heat and shock from continuous impact between the movable unit 30a and the boundary of the range of movement of the movable unit 30a.

Further, if the dust removal operation is halted once, the dust removal operation can be resumed after the third time period (10000 ms) from the commencement of counting the number of times of the dust removal operation. So, even if the dust removal operation is temporarily halted, discomfort that the operator of the photographing apparatus 1 feels can be restrained.

In the embodiment, as the dust removal operation, the movable unit 30a is held constant at the center in the first direction x (the longer direction) and moved in the second direction y (the shorter direction), under the condition where the range of movement of the movable unit 30a in the first direction x is longer than that in the second direction y. In this case, the possibility of the removed dust re-adhering can be reduced compared to the case where the movable unit 30a is held constant at the center in the second direction y and moved in the first direction x.

However, the movable unit 30a may be held constant at the center in the second direction y, and moved in the first direction x.

Further, the position where the movable unit 30a is moved to when the dust removal operation commences is not limited to the center of the range of movement of the movable unit 30a. It may be any position where the movable unit 30a does not make contact with the boundary of the range of movement of the movable unit 30a.

Further, it is explained that the hall element is used for position detection as the magnetic-field change-detecting element. However, another detection element, an MI (Magnetic Impedance) sensor such as a high-frequency carrier-type magnetic-field sensor, a magnetic resonance-type magnetic-

field detecting element, or an MR (Magneto-Resistance effect) element may be used for position detection purposes. When one of either the MI sensor, the magnetic resonance-type magnetic-field detecting element, or the MR element is used, the information regarding the position of the movable unit can be obtained by detecting the magnetic-field change, similar to using the hall element.

Although the embodiment of the present invention has been described herein with reference to the accompanying drawings, obviously many modifications and changes may be made by those skilled in this art without departing from the scope of the invention.

The present disclosure relates to subject matter contained in Japanese Patent Application No. 2006-276860 (filed on Oct. 10, 2006), which is expressly incorporated herein by reference, in its entirety.

The invention claimed is:

1. A dust removal apparatus of a photographing apparatus, comprising:

a movable unit that has an imaging device and that is movable; and

a controller that strikes said movable unit against a boundary of a range of movement of said movable unit as a dust removal operation, said controller counting the number of times that said dust removal operation is performed and measuring an elapsed time from a point when counting said number of times that said dust removal operation is performed commences;

when said elapsed time is less than or equal to a time period and said number of times that said dust removal operation is performed is equal to or greater than a predetermined number of times, said controller halting said dust removal operation until a predetermined time period has elapsed.

2. The dust removal apparatus according to claim 1, further comprising a dust removal switch that is used for switching between whether or not said dust removal operation is performed;

wherein said controller performs said dust removal operation when said dust removal switch is set to the ON state and said elapsed time exceeds said time period, or when said dust removal switch is set to the ON state and said elapsed time is less than or equal to said time period and said number of times that said dust removal operation is performed does not exceed said predetermined number of times.

3. The dust removal apparatus according to claim 1, wherein said movable unit is movable on a plane that is parallel to a first direction and a second direction, said first direction being perpendicular to an optical axis of a photographing optical system that captures an optical image on a photographing surface of said imaging device, said second direction being perpendicular to said first direction and to said optical axis; and

said controller moves said movable unit to a predetermined position that does not make contact with said boundary of said range of movement, and strikes said movable unit against said boundary of said range of movement in said second direction while a coordinate value in said first direction of said movable unit is held constant, to perform said dust removal operation.

4. The dust removal apparatus according to claim 1, wherein repeated impact of said movable unit with said boundary in said second direction to perform said dust removal operation is executed such that said controller moves said movable unit to strike against one side of said boundary in said second direction, to strike against an other side of said boundary in said second direction, and to again strike against said one side of said boundary in said second direction, in this order.

5. The dust removal apparatus according to claim 1, wherein said controller moves said movable unit in said range of movement for an anti-shake operation for image stabilizing; and

said dust removal operation is performed before said anti-shake operation commences.

6. The dust removal apparatus according to claim 1, wherein said predetermined time period elapses when said elapsed time exceeds said time period.

7. The dust removal apparatus according to claim 1, wherein said elapsed time is reset to 0 when said elapsed time exceeds said time period, so that said elapsed time is measured again.

8. The dust removal apparatus according to claim 1, wherein said controller moves the movable unit to a predetermined position before commencing the dust removal operation.

9. The dust removal apparatus according to claim 8, wherein the predetermined position is a center of the range of movement.

10. The dust removal apparatus according to claim 1, wherein a force of impact of a first strike of the movable unit with a boundary of the range of movement is less than a force of impact of a second strike of the movable unit with a boundary of range of movement.

11. The dust removal apparatus according to claim 1, a buffer member being provided at a position where the movable unit strikes against the boundary of the range of movement of the movable unit.

12. The dust removal apparatus according to claim 1, the range of movement for the dust removal operation being defined by a fixed member of an anti-shake mechanism.

13. The dust removal apparatus according to claim 1, said controller being configured to enable the dust removal operation to resume after the elapse of the predetermined time period.

14. The dust removal apparatus according to claim 1, wherein each strike by the movable unit against a boundary of the range of movement of the movable unit serves to remove dust from the imaging device of the movable unit.

15. The dust removal apparatus according to claim 1, the imaging device having a rectangular shape with a first side that is longer than a second side that extends in a direction transverse to the first side, and in the dust removal operation the movable member is held and a constant coordinate corresponding to a center of the first side and moved in a direction of the second side.

16. The dust removal apparatus according to claim 1, wherein said imaging device is movable together with said movable unit to perform the dust removal operation.